LAHET Calculations for Accelerator Neutron Production

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Published in: *American Nuclear Society Transactions, 69,*

San Francisco, Nov. 14 to Nov. 18, 1993, p. 426.

Introduction

LAHET is a Monte Carlo code for the transport and interaction of nucleons, pions, muons, light ions, and antinucleons in complex geometry[1]; it is the result of a major effort at Los Alamos National Laboratory to develop a code system based on the LANL version of the HETC Monte Carlo code for the transport of nucleons, pions, and muons, which was originally developed at Oak Ridge National Laboratory[2]. The system of codes based on LAHET is designated as the LAHET Code System (LCS)[1]. LAHET, as all the variants of HETC, has been widely used over the years for design of neutron production targets, facility shielding, and experimental analysis. LAHET is now widely used for medical accelerator facility design and application.

Particle tracking uses the general geometry model of the LANL MCNP code[3], and shares the geometry description and input of MCNP, except for lattices and/or repeated structures. HMCNP is a modification of MCNP which accepts an external neutron/photon source created by LAHET. Neutron transport from 20 MeV to thermal and all photon/electron transport is done with HMCNP.

Benchmarking Neutron Production

LAHET results for neutron spectra for a variety of targets and angles have been published for 113 MeV and 256 MeV data. A full benchmark document for thin target calculations at 597 MeV and 800 MeV will soon be released. These benchmark calculations show the effect of physics model development for LAHET, including a preequilibrium exciton model which enhances high energy neutron emission at back angles and a Fermi breakup model for light nuclei.

A LANL experiment for ATW target compositions is being evaluated as a benchmark for computational methods. Overall neutron production is obtained from thermal activation in a water bath surrounding target and blanket.

Benchmarking the Fission Models

Other benchmarking efforts have been devoted to the two high energy fission models implemented in LAHET. Current results for actinide fission data to 400 MeV show reasonable agreement with experiment; an example is shown in Figure 1. Subactinide fission is much less well represented by the present model, as indicated in Figure 2 for ^{208}Pb. Although subactinide fission contributes little to neutron production in lead or tungsten targets, it can be significant for simulation of target activation and fission product contamination.

Activation and Dosimetry

Beyond the general topic of neutron production and transport calculations, LAHET is being extensively used in activation calculations. For such calculations, the residual nuclide production from LAHET and the low-energy neutron fluxes from MCNP are used as input to the CINDER code to calculate a time-dependent activation source. The CINDER resulted may then be used to provide a spatially-distributed gamma source for a subsequent HMCNP gamma dose calculation. The greatest limitation in this method is the uncertainty in the residual nuclide distribution obtain from the intranuclear cascade-evaporation model; coming as it does at the end of a long chain of model calculations, it is most sensitive to the inherent limitations of the physics models.

Summary

The LAHET Code System is being used for increasingly difficult calculations. Benchmark calculations at energies below 100 MeV, and concurrent model development, are certainly called for, as this energy region tends to violate the assumptions of the models. Improved models for subactinide fission could be developed, but more extensive data to 500 MeV or above would be desirable. Benchmarking the calculated residual nuclide distribution is highly desirable; the increase in interest in activation and dosimetry calculations indicated a need to quantify the limitations of the methods used.

1. Richard E. Prael and Henry Lichtenstein, "User Guide to LCS: The LAHET Code System", LA-UR-89-3014, Los Alamos National Laboratory (September 1989).
2. Radiation Shielding Information Center, " HETC Monte Carlo High-Energy Nucleon-Meson Transport Code", Report CCC-178, Oak Ridge National Laboratory (August 1977).
3. Group X-6, "MCNP - A General Monte Carlo Code for Neutron and Photon Transport", LA-7396-M Revised, Los Alamos National Laboratory (1981).

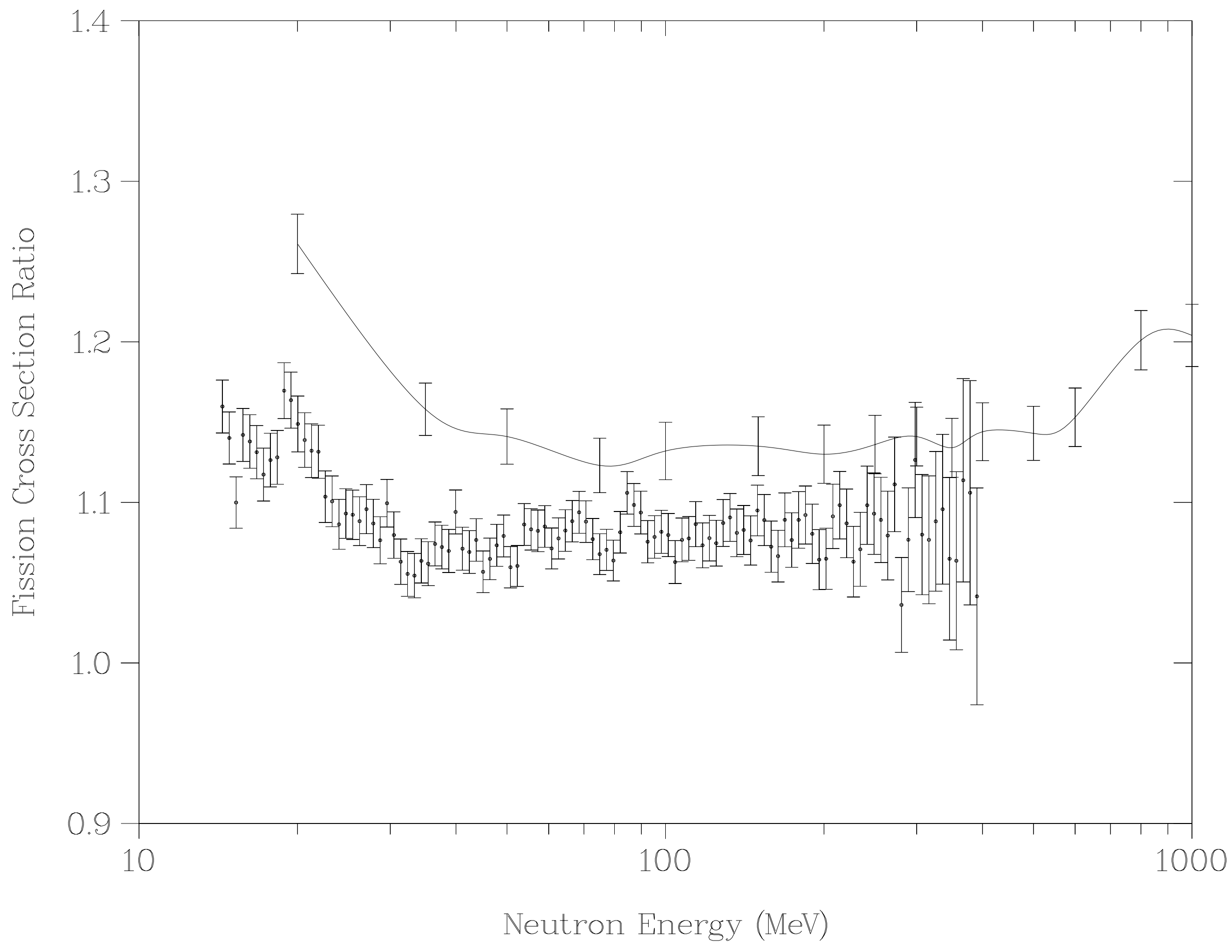

Figure 1: Neutron induced fission ratio $^{239}Pu/^{235}U$. LAHET calculations with Bertini INC and default physics options (line). Data of Lisowski et al.

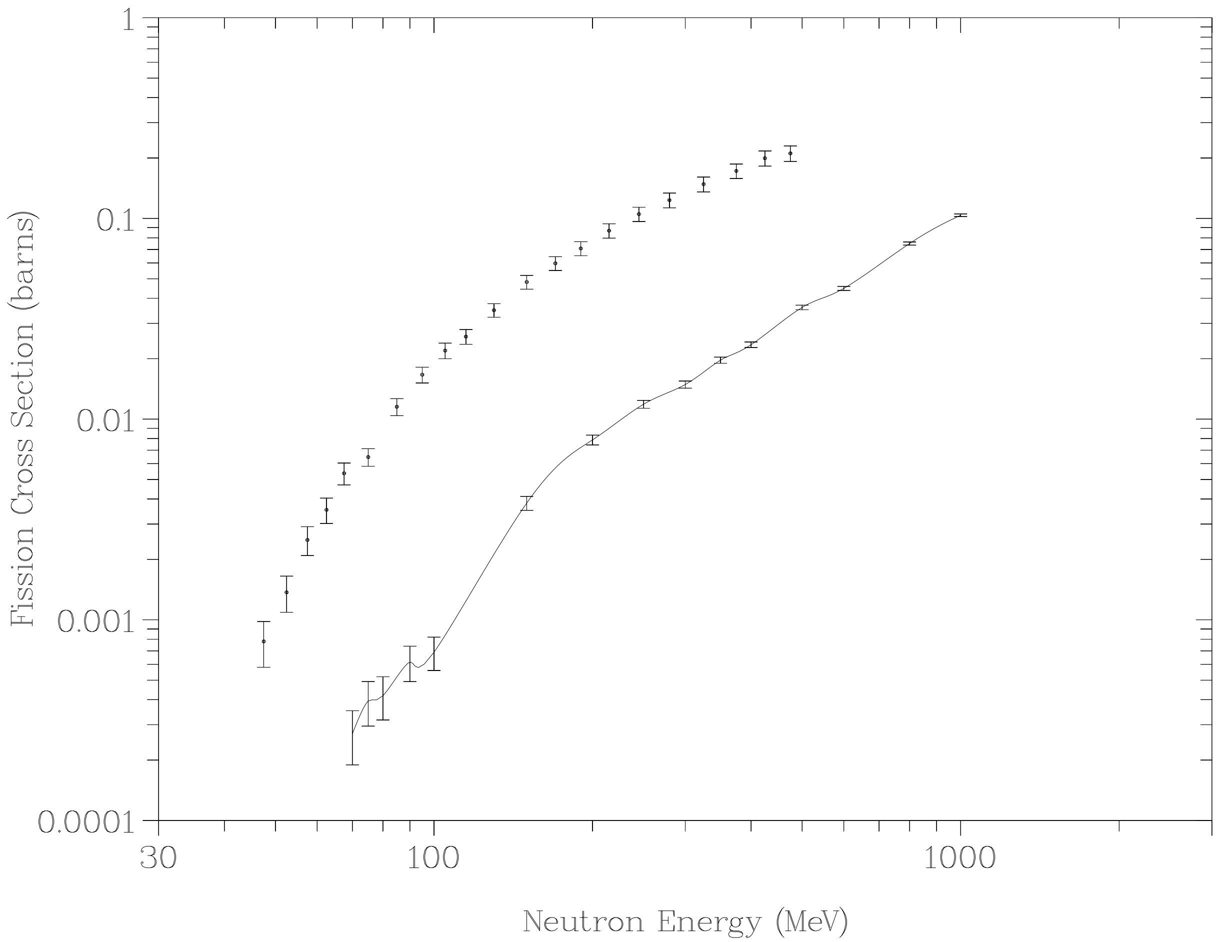

Figure 2: Neutron induced ^{208}Pb fission cross section. LAHET calculations with Bertini INC and default physics options (line). Data of Vonach et al.